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Moisture Properties of Low Density Aircrete

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Abstract*-*The moisture properties of low density aircrete (compressive strength of 2.8 and 2N/mm^2) are verified. This entails determining the moisture content after immediately removing from the pallet, measuring the water absorption rate and finally evaluating the shrinkage on drying. The tests were carried out in accordance with the relevant British and European Standards. Low density aircrete has a low water absorption rate with minimal shrinkage on drying from a moistened state.
Aircrete, masonry, moisture properties

I. INTRODUCTION

Aircrete originated from Scandinavia in the 1950's [1] and is used extensively in the United Kingdom. Aircrete is also known commercially as AAC (Autoclaved Aerated Concrete), Celcon, Durox, Thermalite and Top block. Aircrete blocks provide both the thermal insulation and mechanical integrity expected from typical UK wall construction [2]. Aircrete is produced by mixing cementitious materials, cement and/or pulverized fuel ash (PFA), lime, sand, water and aluminum powder. The final process involves autoclaving for approximately 10 hours at high temperature and pressure [3]-[6]. Hence, the material is also known as autoclaved aerated concrete. Aircrete is comprised of 60% to 85% of air by volume (70–85% for low density aircrete). The solid material part is a crystalline binder, which is called tobermorite by mineralogists. It is tobermorite, which provides the high compressive strength of aircrete in spite of the high proportion of pores in this construction material. This is why low density aircrete is sufficiently strong for the construction of dwellings in spite of its considerably high air content. The cellular (porous) structure [7]-[15] of the material ensures a lightweight construction. During installation, most aircrete blocks can be lifted with one hand providing significant productivity advantages. The higher porosity of low density aircrete ensures that the material is extremely lightweight (density $\leq$ 450 kg/m^3), thus, it is even easier to handle in comparison to medium and high density aircrete. As a result transportation costs would be reduced and furthermore, houses would be built much more quickly. The high degree of porosity of aircrete has a dramatic influence on thermal conductivity; increasing pore volume will, under most circumstances reduce thermal conductivity and increase thermal insulation. Heat transfer across pores is ordinarily slow and inefficient [2], [7], [8]. Internal pores normally contain still air, which has extremely low thermal conductivity - approximately 0.02 W/m-k. Furthermore, gaseous convection within the pores is also comparatively ineffective. Hence low density aircrete has outstanding thermal insulation properties [5], [9]-[15]. The combination of the internal structure and the stiffness characteristics of aircrete enable sound reduction performance for walls and partitions often superior to other types of masonry [6]-[19]. Sound absorption is a property relevant to particular applications. When exposed to sound, the aerated internal structure of aircrete provides good sound absorption properties. Therefore, lower density aircrete should impart superior sound insulation properties. Moisture movement through porous building materials is a very complex process [16], [20] and for practical predictions simplifying assumptions have to be introduced. There are at least three different origins of water in aircrete. Immediately after autoclaving aircrete contains typically about 30% water by weight of the dry material. This excess water is lost under normal conditions to the surrounding air after a few years [5]. If the relative humidity of the surrounding air increases temporarily, aircrete will take up water again by absorption and capillary condensation. If the surface of a structural element is in contact with liquid water the material absorbs water quickly by capillary suction [6,20]. Although Low Density Aircrete has a very high proportion of air, the pores are fine and are not interconnected; therefore, the material offers good resistance to moisture penetration. Vapour resistivity of aircrete is approximately 60MNs/gm [6], [20], [22], [23].

The resistance to freezing of a construction material is determined by its pore size distribution and, in particular, the percentage, size and shape of capillary pores and the mechanical strength of the inner pore walls [16], [22], [23]. If the pores of the material become filled with water, which then freezes, the ice, which has a volume 9% greater than water will cause pressure on the pore walls. When the tensile strength of the wall material is exceeded, cracking occurs. If the pores are filled with water to a critical degree, and if there is repeated freeze/thaw cycling, the whole structure may eventually be destroyed. Aircrete possesses good resistance to freezing [1], [2], [9] which is proved by unrendered buildings, situated in areas where frequent freeze/thaw cycles occur, remaining undamaged. The reason for the good resistance is that the included spherical pores are almost all closed, meaning the material has comparatively low capillary suction and therefore the moisture content does not normally reach the critical degree. With low density aircrete, the greater free volume of the material is better equipped for dealing with the pressures caused by freezing of water. Furthermore, as discussed earlier, as the pores are not interconnected, this radically reduces the possibility of water absorption. The high freeze thaw resistance in essence is due to the aerated internal structure of the material. The resistance to frost is superior to that of many stronger denser masonry materials although the degree of resistance is to some extent dependent on

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strength and density [16], [20],[22], [23]. Since the Kyoto summit in 1997, the UK is committed (along with other countries) to reducing greenhouse gas emissions. One way of achieving this is by constructing dwellings and buildings with better thermal insulation, as this would require less energy for heating. As elaborated earlier aircrete has excellent thermal insulation properties, therefore, by utilising especially lower density material can lead to greater thermal insulation for UK dwellings, however, it is important to evaluate the physical properties of the material. This paper reports the findings of a study undertaken (as part of an extensive testing programme) to verify the moisture properties of low density aircrete.

II. MATERIAL AND METHODS

This paper describes the results achieved for verifying the moisture properties of low density aircrete using 2.8 and 2N/mm^2 compressive strength blocks (provided by H + H Celcon); aircrete is typically comprised of sand, cement, lime, pulverised fuel ash and aluminium oxide; the precise mixture proportions are not disclosed by the manufacturers. The size of blocks were 440 x 215 x 150mm for 2.8 N/mm^2 and 620 x 215 x 150mm for 2 N/mm^2 blocks.

A. Moisture Content (By Mass)

Tests were carried out in accordance with BS EN 772-10 [24]. In essence, during this test, after drying to constant mass, the moisture content is calculated as the ratio of the loss of mass during drying to the mass after drying. According to BS EN 772-10 [24], a minimum of 6 representative portions from at least three units must be tested. The moisture content should also be measured immediately after removing the blocks from the pallets.

B. Water Absorption

The method for determining the water absorption property is carried out in accordance with BS EN 772-11 [25]. After drying to constant mass a face of the aircrete block is immersed in water for a specific period of time, as BS EN 771-4 [26] specifies that the coefficient of water absorption should be stated at 10, 30 and 90 minutes, tests were carried out at these immersion times. The water absorption of face of the unit exposed is measured. Tests were carried out on both 2 and 2.8N/mm2 standard aircrete blocks. The test set – up is shown in Figure 1. Testing is undertaken on 6 specimens of each aircrete material.

C. Moisture Movement

The moisture movement of 2.0 and 2.8 N/mm2 aircrete is measured in accordance with BS EN 680 [27]. Prismatic test specimens are cut from prefabricated components (blocks) and, if necessary, moistened by underwater storage until their moisture content is at least 30 % by mass. Subsequently, the test specimens are stored in air under specified conditions until a moisture content of 4% by mass has been reached, and changes of length and mass are determined at appropriate intervals. Finally, the test specimens are dried to constant mass to enable the calculation of the moisture content from the mass of the test specimen recorded at each measuring date. The samples and apparatus used are shown in Figure 2. In order to avoid faulty readings due to the presence of dirt, the DEMEC points were wiped carefully before each measurement. Points were attached to all four sides of prisms, which had a cross – section of 40 x 40 mm and a length of 160mm. After the DEMEC points dried the first reading of the gauge length and the first measurement of mass, mo, of the test specimens was made. The specimens were then moistened by underwater storage to ensure their moisture content was at least 30% by mass. Readings of the gauge length and accompanying measurements of the mass of the test specimens were executed at regular time intervals until the moisture content was less than 4% by mass; specimens were then dried to a constant mass.

Fig 1. Test set-up for water absorption test. The block is immersed in water to a depth of 5 mm ± 1mm. Continuous water flow ensures constant water level.

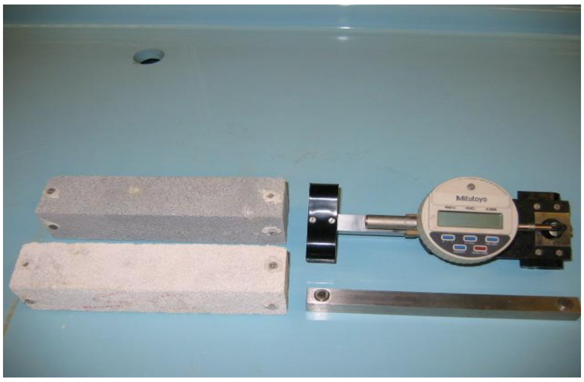

Fig 2. Test apparatus and specimens with DEMEC points attached to the surface used for the evaluation of Moisture Movement.

III. RESULTS

A. Moisture Content by Mass

Table 1 gives results of the moisture content of aircrete specimens as delivered obtained for 2 and 2.8 N/mm^2 aircrete blocks. The moisture content is calculated as follows [24]:

$$W_s = \frac{M_{o,s} - M_{dry,s}}{M_{dry,s}} \times 100 \quad (1)$$

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Where W_s = moisture content (%); $M_{o,s}$=mass of specimen before drying, in grams; $M_{dry,s}$ =mass of specimen after drying, in grams.

Aircrete block strength (N/mm^2)	Moisture content, % by mass
	11.7
	18.3
2	7.4
	18.0
	11.3
	15.3
	11.1
	11.2
2.8	10.8
	13.3
	16.2
	18.9

Table 1. Moisture Content by Mass for Low Density Aircrete

The average moisture content therefore for both materials are:

a) 2 N/mm^2 aircrete = 13.7%
b) 2.8 N/mm^2 aircrete = 13.6%

B. Water Absorption

Results of the coefficient of water absorption due to capillary action over short term exposure times are given in Tables 2 and 3.

Table 2. Coefficient of Water Absorption of 2N Aircrete Blocks at Short Exposure Times.

2N/mm² Aircrete block sample	Mass (gm) Initial	Mass (gm) Final	Time (Sec) [mins]	Area (mm^2)	$C_{w,s}$ [$g/(m^2s^{0.5})$]
		3668	600 [10]	46216	160.8
1	3486	3744	1800 [30]	46216	131.6
		3870	5400 [90]	46216	113.1
		3668	600 [10]	47300	163.1
2	3479	3739	1800 [30]	47300	129.6
		3856	5400 [90]	47300	108.5
		3674	600 [10]	46866	170.7
3	3478	3747	1800 [30]	46866	135.3
		3871	5400 [90]	46866	114.1
		3588	600 [10]	46655	159.3
4	3406	3661	1800 [30]	46655	128.8
		3762	5400 [90]	46655	103.8
		3662	600 [10]	46434	153.0
5	3488	3731	1800 [30]	46434	123.4
		3848	5400 [90]	46434	105.6
		3631	600 [10]	46221	147.6
6	3448	3705	1800 [30]	46221	131.1
		3841	5400 [90]	46221	115.7

2N/mm² Aircrete block sample	Mass (gm) Initial	Mass (gm) Final	Time (Sec) [mins]	Area (mm^2)	$C_{w,s}$ [$g/(m^2s^{0.5})$]
		2314	600 [10]	43460	105.2
1	2202	2356	1800 [30]	43460	83.5
		2398	5400 [90]	43460	61.4
		2141	600 [10]	42158	87.2
2	2051	2166	1800 [30]	42158	64.3
		2212	5400 [90]	42158	52.0
		1954	600 [10]	36575	78.1
3	1884	1986	1800 [30]	36575	65.7
		2026	5400 [90]	36575	52.8
		2459	600 [10]	44908	128.2
4	2218	2501	1800 [30]	44908	96.0
		2537	5400 [90]	44908	66.4
		2224	600 [10]	43263	74.5
5	2145	2261	1800 [30]	43263	63.2
		2305	5400 [90]	43263	50.3
		2376	600 [10]	4100	144.3
6	2211	2419	1800 [30]	4100	99.6
		2463	5400 [90]	4100	63.6

Table 3. Coefficient of Water Absorption of 2.8N Aircrete Blocks at Short Exposure Times.

Aircrete block strength (N/mm^2)	Soaking time (sec) [mins]	Average $C_{w,s}$ [$g / (m^2 \times s^{0.5})$]
	600 [10]	102.9
2	1800 [30]	78.7
	5400 [90]	57.8
	600 [10]	159.1
2.8	1800 [30]	129.0
	5400 [90]	110.1

Table 4. Average short term soaking times for 2 and 2.8N Aircrete.

The coefficient of water absorption is calculated as follows [25], [26]:

$$C_{w,s} = \frac{m_{so,s} - m_{dry,s} \times 10^6}{A_s (t_{so})^{0.5}} \quad [g/(m^2s^{0.5})] \qquad (2)$$

where $m_{dry,s}$ = mass of the specimen after drying (gm); $m_{so,s}$ = mass of the specimen in grams after soaking for time t, (gm); A_s = gross area of the face of specimen immersed in water (mm^2); t_{so} = time of soaking (sec).

The average $C_{w,s}$ for both 2 and 2.8 N/mm^2 aircrete for short soaking times is summarised below on Table 4.

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In general, the coefficient of water absorption was found to be greater for 2.8N/mm^2 aircrete material. This is as expected as the rate of absorption is determined by the dry density of the material [28], [29]. Also, the C_{ws} for both materials reduced with increasing soaking time as expected.

C. Moisture Movement

Fig 3 and 4 show the graphs of moisture movement for both 2 and 2.8N/mm^2 aircrete blocks.

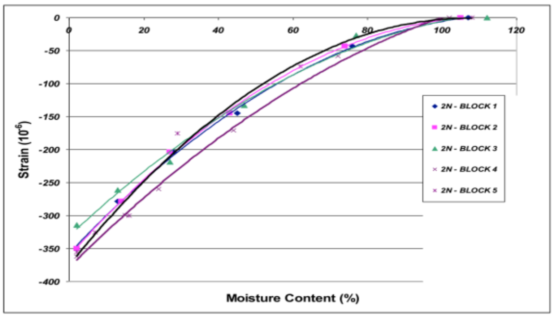

Fig 3. Graph of Moisture Movement for 2N Aircrete using DEMEC Points.

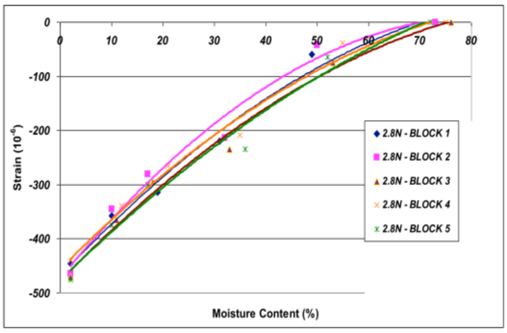

Fig 4. Graph of Moisture Movement for 2.8N Aircrete using DEMEC Points.

For comparative purpose, if the strain for both materials is assessed from 40% moisture content down to 2%, the shrinkage (or ε) is 200 x 10^{-6} and 310 x 10^{-6}, respectively for 2 and 2.8N/mm^2 aircrete. This is due to the greater density material having a higher shrinkage rate. These values, however, are very low in comparison to other construction materials [7]. It should also be noted there is remarkably good consistency shown by both materials as depicted in Figures 4 and 5.

IV. CONCLUSION

a) Three different test methods have been used to assess and examine the moisture properties of aircrete blocks in accordance to British and European standards.

b) The average moisture content of 2 and 2.8N/mm^2 blocks on immediate removal from the pallet was recorded to be 13.7% and 13.6% respectively.

c) The average coefficient of water absorption ($C_{w,s}$) for 2 and 2.8N/mm^2 blocks after 90 minutes soaking time was found to be 57.8 and 110.1 [g / (m^2 x s$^{0.5}$)], respectively. This indicates greater $C_{w,s}$ for the higher density material.

d) Moisture movement tests revealed the higher density material imparting a larger shrinkage rate.

V. ACKNOWLEDGMENT

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